ABG
(Arterial Blood Gas)

The basic physiology of acid –base balance

- Our body functions in a relatively narrow alkaline environment
  - pH: 7.35-7.45
- Normal physiologic function = the maintenance of pH within this range.
- Two main mechanisms – Respiratory and Metabolic.
- If pH <7.35, the blood is said to be <u>acidic.</u>
- If pH >7.45, the blood is said to be <u>alkalotic.</u>

The respiratory buffer response

- Carbon dioxide (CO_2) is a normal by-product of cellular metabolism.
- Partial pressure of CO_2 in arterial blood (paCO2) is determined by alveolar ventilation.
- The excess CO_2 combines with water to form carbonic acid.
- The blood pH changes according to
  - Amount of carbonic acid in the body i.e. the depth and rate of ventilation.
- As blood pH decreases (acidosis), CO_2 is exhaled (alkalosis as compensation).
- As blood pH increases (alkalosis), CO_2 is retained (acidosis as compensation).
- The respiratory response is fast and activated within minutes.

The renal buffer response

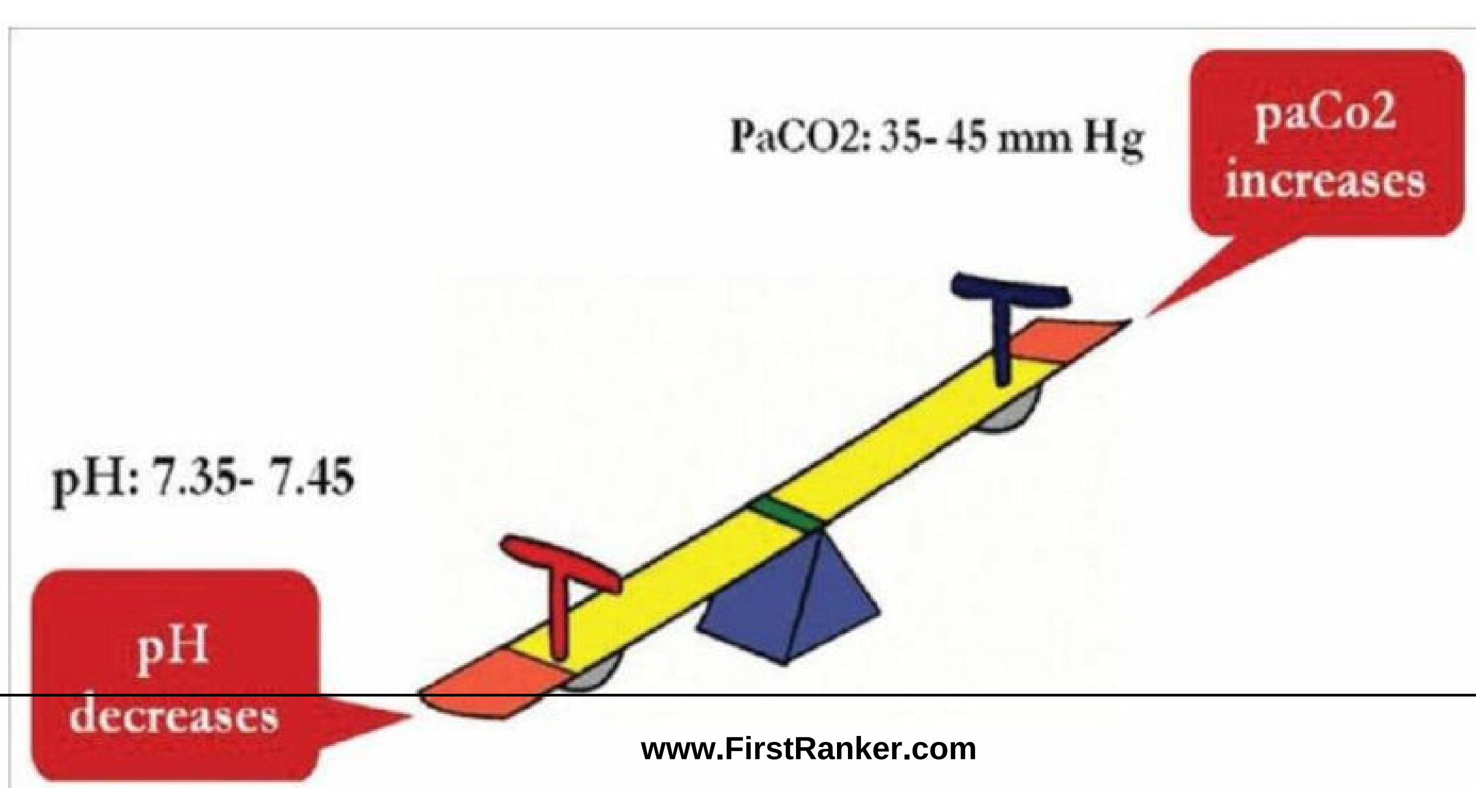
- The kidneys secrete Hydrogen ion (H^+) and reabsorbs bicarbonate.
- In response to metabolic acid formation.
- Bicarbonate is a metabolic component and considered a base.
- As blood pH decreases (acidosis), the body retains bicarbonate (a base).
- As blood pH rises (alkalosis), the body excretes bicarbonate (a base) in urine.
- This compensation is slow and takes hours to days to get activated.

The acid-base control

- The pH is dependent on the paCO2 /HCO3- (bicarbonate) ratio.
- A change in CO2 ➡ compensated by a change in HCO3- and vice versa.
- The initial change is called the primary disorder.
- The secondary response is called the compensatory disorder.

Basic facts to remember

- CO2 is a respiratory component and considered a respiratory acid.
- Moves opposite to the direction of pH and is visualized as a see-saw



Basic facts to remember…….

- Bicarbonate - A metabolic component and considered a base.
- It moves in the <u>same direction</u> as pH and is visualized as <u>an elevator</u>

Basic facts to remember…….

- If CO2 and HCO3- move in the <u>same direction</u>, it is considered a <u>primary disorder</u>.
  - For example, if there is respiratory acidosis in body (CO2 retention), the bicarbonate levels increase as a compensation (metabolic alkalosis). The direction of both CO2 and HCO3- are the same in this case.
- If CO2 and HCO3- move in <u>opposite directions</u>, it is considered a <u>mixed disorder</u>.
  - For example, mixed disorder in the case of salicylate poisoning: Primary respiratory alkalosis due to salicylate-induced hyperventilation and a primary metabolic acidosis due to salicylate toxicity.

Conditions causing acid-base imbalance

- Respiratory acidosis
  - Any condition causing the accumulation of CO_2 in the body.
  - Central nervous system (CNS) depression due to head injury
  - Sedation, coma
  - Chest wall injury, flail chest
  - Respiratory obstruction/foreign body

- Respiratory alkalosis
  - Due to decrease in CO_2 . Hyperventilation occurs and CO_2 is washed out causing alkalosis.
  - Psychological: Anxiety, fear
  - Pain
  - Fever, sepsis, pregnancy, severe anemia.

Conditions causing acid-base imbalance

- Metabolic acidosis -due to excess of acids or deficit of base.
  - Increased acids
    - Lactic acidosis (shock, haemorrhage, sepsis)
    - Diabetic ketoacidosis
    - Renal failure
  - Deficit of base
    - Severe diarrhoea
    - Intestinal fistulas.

- Metabolic alkalosis - caused by excess base or deficit of acids.
  - Acid Deficit:
    - Prolonged vomiting, nasogastric suction, diuretics
  - Excess base:
    - Excess consumption of diuretics and antacids
    - massive blood transfusion (citrate metabolized to bicarbonate).

Arterial blood gas analysis

- Important routine investigation to monitor
  - the acid-base balance of patients
  - effectiveness of gas exchange
- A vital role in monitoring of
  - Postoperative patients,
  - Patients receiving oxygen therapy,
  - Those on intensive support,
  - Patients with significant blood loss, sepsis, and comorbid conditions like diabetes, kidney disorders,
  - Cardiovascular system (CVS) conditions

Why do we order a blood gas analysis?

- Aids in establishing diagnosis
- Guides treatment plan
- Improvement in the management of acid/base; allows for optimal function of medications
- Acid/base status may alter levels of electrolytes critical to the status of a patient.

- **Limitations of blood gas analysis**
  - Can not yield a specific diagnosis. (e.g. A patient with asthma may have similar values to another patient with pneumonia).
  - Does not reflect the degree to which an abnormality actually affects a patient.
  - Cannot be used as a screening test for early pulmonary disease.

Arterial vs Venous blood gas analysis

- Arterial blood → paO2, paCO2, and pH measurements.
- Best indicator → How well the lungs are oxygenating.

H^+	Hydrogen ions, inversely proportional to pH	35-45 mmol/L
pH	Acidity/alkalinity	7.35-7.45
paO_2	Partial pressure of oxygen in arterial blood	80-100 mmHg
SaO_2	Arterial oxygen saturation	95-100%
$paCO_2$	Partial pressure of CO_2 in arterial blood	35-45 mm Hg
HCO^{3-}	Bicarbonate in blood	22-26 mEq/L
BE	Base excess (amount of excess or insufficient amount of base in blood) −ve in acidosis, +ve in alkalosis	−2 to+2 mmol/L

CO_2: Carbon dioxide

Arterial vs Venous blood gas analysis

- If the venous sample is obtained
  - ➢Values compared and interpreted keeping in consideration.

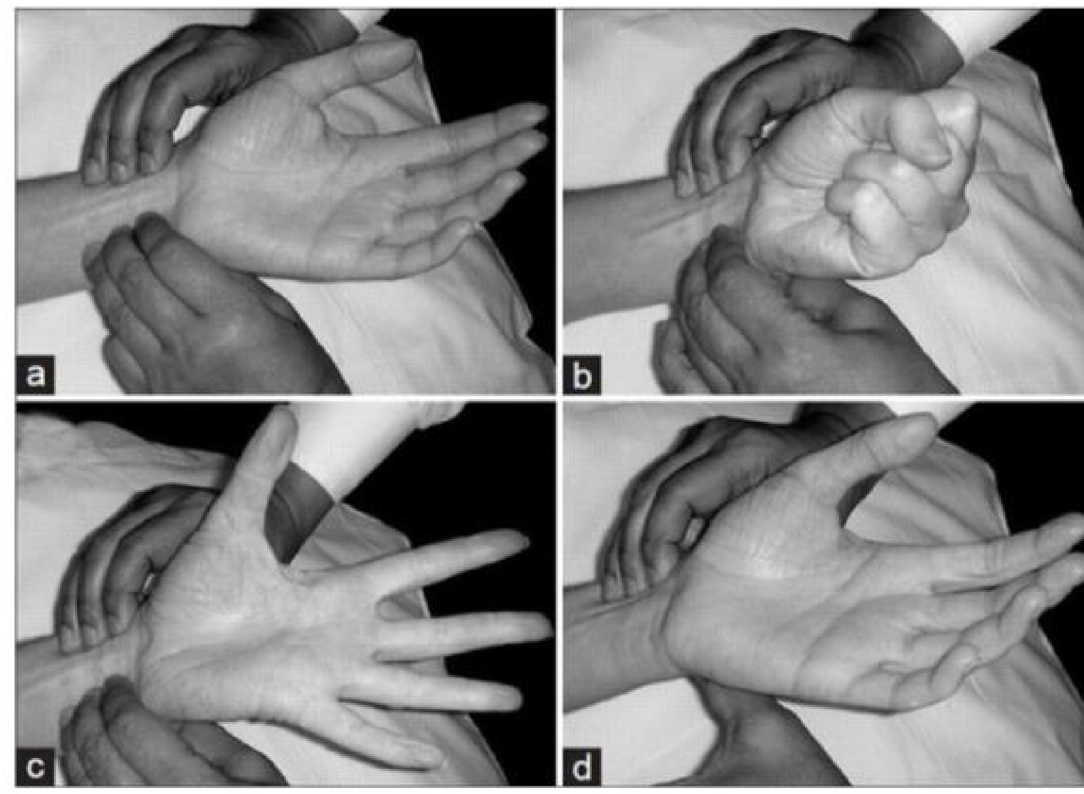
Value	Arterial blood	Mixed venous
pH	7.40 (7.35-7.45)	7.36 (7.31-7.41)
paO_2	80-100 mmHg	35-40 mmHg
O_2 saturation	95%	70-75%
$PaCO_2$	35-45 mmHg	41-51 mmHg
HCO^{3-}	22-26 $mEqL^{-1}$	22-26 $mEqL^{-1}$
BE	−2 to + 2	−2 to + 2

(Table adapted from[3]); O_2: Oxygen, paO_2: Partial pressure of oxygen in arterial blood, pH: Acidity/alkalinity, $PaCO_2$: Partial pressure of oxygen in arterial blood, HCO^{3-}: Bicarbonate in blood, BE: Base excess

  - ➢Significance in hemodynamically unstable patients and should not be discarded.

Obtaining an arterial sample

- Order of preference:
  - ➢ Radial > brachial >femoral artery.
- Radial artery is preferred:
  - ➢ ease of palpation and access
  - ➢ good collateral supply.
- Collateral supply to the hand:
  - ➢ Confirmed by the modified Allen's test



Modified Allen's test

- Ask the patient to make a tight fist.
- Apply pressure to the wrist:
  - ➢ Using the middle and index fingers of both hands
  - ➢ Compress the radial and ulnar arteries at the same time
- While maintaining pressure:
  - ➢ ask the patient to open the hand slowly.
  - ➢ Lower the hand and release pressure on the ulnar artery only.
- **Positive test:**
  - ➢ The hand flushes pink or returns to normal color within 15 seconds
- **Negative test:**
  - ➢ The hand does not flush pink or return to normal color within 15 seconds
  - ➢ indicating a disruption of blood flow from the ulnar artery to the hand
  - ➢ radial artery should not be used.

Sampling

- Arm of the patient
  - palm up on a flat surface
  - wrist dorsiflexed at 45°.
- Puncture site :
  - cleaned with alcohol or iodine
  - allow the alcohol to dry before puncture, as the alcohol can cause arteriospasm
  - local anesthetic (such as 2% lignocaine)
- Radial artery should be palpated for a pulse
- A preheparinised syringe with a 23/25 gauge needle should be inserted at an angle just distal to the palpated pulse.
- After the puncture, sterile gauze should be placed firmly over the site and direct pressure applied for several minutes to obtain hemostasis.

Errors

- Allow a steady state after initiation or change in oxygen therapy before obtaining a sample
  - a steady state is reached between 3 and 10 minutes.
  - in patients with chronic airway obstruction, it takes about 20-30 minutes.
- Always note the percentage of inspired air (FiO_2) and condition of the patient
- Do not use excess heparin as
  - it causes sample dilution
  - Excess of heparin may affect the pH.
- Avoid air bubbles in syringe.
- Avoid delay in sample processing.
  - As blood is a living tissue, O_2 is being consumed and CO_2 is produced in the blood sample.
  - In case of delay, the sample should be placed in ice and such iced samples can be processed for up to two hours without affecting the blood gas values.
- Accidental venous sampling. The venous sample report should not be discarded and can provide sufficient information.

Steps of interpretation

- **Step 1**: Anticipate the disorder
  - keeping in mind the clinical settings and the condition of the patient
  - e.g., the patient may present with a history of insulin-dependent diabetes mellitus (IDDM), which may contribute to a metabolic acidosis
- **Step 2**: Check the pH.
  - pH < 7.35: Acidosis
  - pH > 7.45: Alkalosis
  - pH = 7.40: Normal/mixed disorder/fully compensated disorder
    - (Note: If mixed disorder, pH indicates stronger component)

Steps of interpretation…………..

- **Step 3**: Check SaO2 /paO2

  SaO2 is a more reliable indicator as it depicts the saturation of hemoglobin in arterial blood.

	SaO_2 %	paO_2
Mild hypoxemia	90-94	60-79 mmHg
Moderate hypoxemia	75-89	40-59 mmHg
Severe hypoxemia	<75	<40 mmHg

SaO_2: Arterial oxygen saturation

Note: Always compare the SaO2 with FiO2

. the SaO2 could be within normal range but still much less than FiO2 if the patient is on supplemental oxygen (difference should be less than 10)

Steps of interpretation……….

- Step 4: Check CO2 and HCO3 - (bicarbonate) levels-
  - ➢Identify the culprit

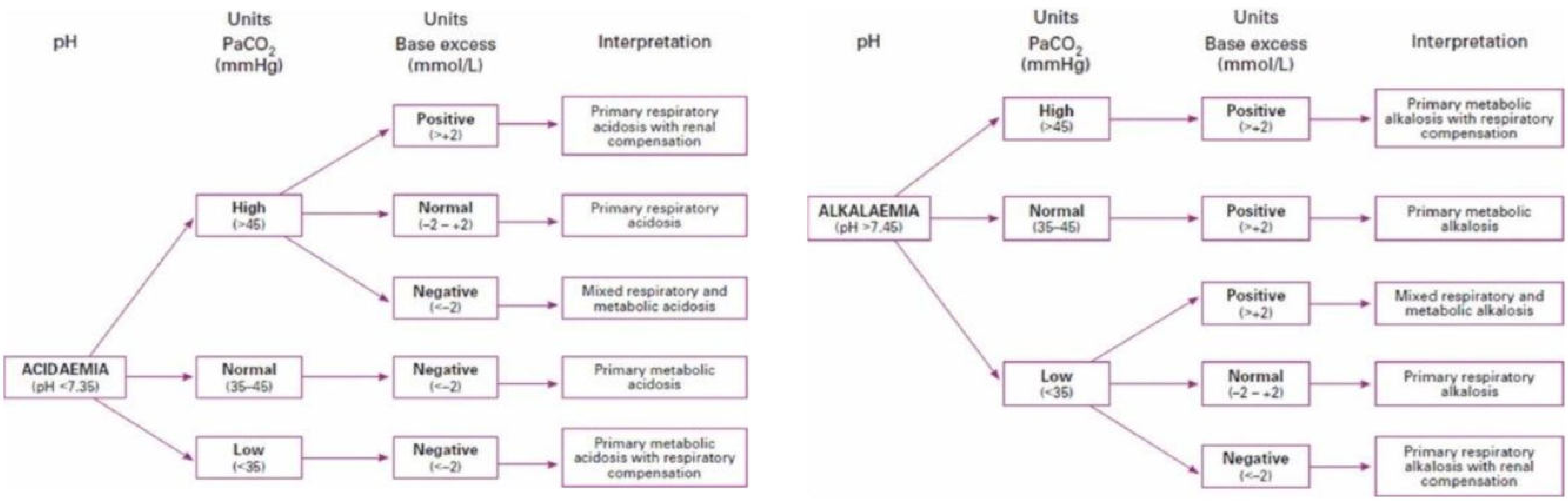
Increased CO_2 (>40 mmHg)	Respiratory acidosis
Decreased CO_2 (<40 mmHg)	Respiratory alkalosis
Increased HCO^{3-} (>24 mEq/L)	Metabolic alkalosis
Decreased HCO^{3-} (<24 mEq/L)	Metabolic acidosis

  - ➢Is it a respiratory/metabolic/mixed disorder?

Steps of interpretation……….

- **Step 5**: Check base excess (BE).
  - Defined as amount of base required to return the pH to a normal range.
  - If it is positive, the metabolic picture is of alkalosis.
  - If it is negative, the metabolic picture is of acidosis.
- Either of bicarbonate ions/base excess can be used to interpret metabolic acidosis/alkalosis.

Interpretation of arterial blood gas report on the basis of using BE as a metabolic index



Steps of interpretation………..

- **Step 6**: Check for compensation.
- Is there a compensatory response with respect to the primary change?
  - If yes: Compensated
  - if no: Uncompensated.
- In case of compensation, does it bring the pH to a normal range?
  - If yes: Fully compensated
  - if no: Partially compensated.

Example: 1

- If pH is 7.21, HCO3- is 14, and CO2 is 40.
  - CO2 is normal
  - HCO3- is decreased

Example: 1

- If pH is 7.21, HCO3- is 14, and CO2 is 40.
  - CO2 is normal
  - HCO3- is decreased
- A case of metabolic acidosis.
- Expected compensation would be a decrease in CO2 causing respiratory alkalosis.
- Now consider this table ---

pH	HCO^{3-}	pCO_2	Compensation
7.21	14	40	Uncompensated
7.21	14	30 ↓	Partially compensated
7.37	14	20 ↓↓	Fully compensated

Example: 2

- *pH: 7.55*, *paCO2: 49.0*, *HCO3 : 48.2*
  - pH: 7.55 alkalosis ↑
  - paCO2: 49.0 increased ↑
  - HCO3: 48.2 increased ↑
- paCO2 is increased - retention of CO2 causes acidosis
- HCO3 is increased - increased base causes alkalosis
- So, the primary disorder is metabolic alkalosis.
- CO2 is being retained to compensate for the same-
  - the pH has still not returned to a normal range.
- So, the interpretation - Partially Compensated Metabolic Alkalosis

Example 3

- *pH: 7.34*, *paCO2 40.3*, *HCO3 : 20.4*.
  - The pH is acidic
  - paCO2 is normal
  - Bicarbonate is decreased.
- Primary disorder is metabolic acidosis
- but no compensatory response as the paCO2 is normal.
- Interpretation - Uncompensated Metabolic Acidosis

Example 4

- pH: 7.52, $paCO_2$: 31.0, HCO_3 : 29.4
  - pH is alkalotic
  - $paCO_2$ is decreased (alkalosis)
  - Bicarbonate is increased (alkalosis).
- As the directions of $paCO_2$ and bicarbonate are opposite and both are causing alkalosis.
- The picture is suggestive of a mixed disorder.
- Interpretation - Combined Alkalosis